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SUMMARY AND EVALUATION OF THE PARAMETRIC STUDY OF POTENTIAL EARLY COMMERCIAL MHD POWER PLANTS (PSPEC)

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Work performed for
U.S. DEPARTMENT OF ENERGY
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Prepared for
Seventh International Conference on Magnetohydrodynamic Electric Power Generation sponsored by the Symposia on the Engineering Aspects of Magnetohydrodynamics, Inc.
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NOTICE

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Summary

The "Parametric Study of Potential Early Commercial MHD Power Plants" is described and the results of the study are summarized. Two parallel contracted studies were conducted. Each contractor investigated three base cases and parametric variations about these base cases. Each contractor concluded that two of the base cases (a plant using separate firing of an advanced high temperature regenerative air heater with fuel from an advanced coal gasifier and a plant using an intermediate temperature metallic recuperative heat exchanger to heat oxygen enriched combustion air) were comparable in both performance and cost of electricity. The contractors differed in the level of their cost estimates with the capital cost estimates for the MHD topping cycle and the magnet subsystem in particular accounting for a significant part of the difference. The impact of the study on the decision to pursue a course which leads to an oxygen enriched plant as the first commercial MHD plant is described.

Introduction

The "Parametric Study of Potential Early Commercial MHD Power Plants" (PSPEC)[1,2] was initiated to assess the potential of "moderate technology" open cycle MHD/steam power plants. The study parametrically investigated power plant configurations with the potential for more near term commercial implementation than advanced MHD plants such as those studied in ECAS[3,4]. The major emphasis of this study was to identify attractive power plant configurations that do not require the development of the high-temperature regenerative MHD-generator-exhaust-gas-to-air heat exchangers used in the ECAS plant. The power plants studied were to have acceptable performance and cost of electricity but lower development costs and/or development times than the more advanced ECAS plant. The PSPEC study was carried out under contract to NASA Lewis Research Center and funded by the Department of Energy under an interagency agreement. Supplementary work was also performed in-house at NASA Lewis to help define, guide, and compare the results of the contracted studies.

Two contractor teams were selected to conduct parallel studies. One team was led by the Avco Everett Research Laboratory, Inc., and included Combustion Engineering, Inc., and Chas. T. Main, Inc., as subcontractors. The other team was led by the General Electric Company Space Sciences Laboratory and included the Foster Wheeler Development Corp., Bechtel National, Inc., the Hooker Chemical Company, and the General Electric Company Energy Systems Programs Department as subcontractors.

Each contractor team considered parametric variations about three base case plants. The base cases were

(1) A power plant with a separately-fired high temperature air heater using state-of-the-art gasifier and heat exchanger technology;

(2) A power plant with a separately-fired high temperature air heater using advanced gasifier and heat exchanger technology;

(3) A power plant with only a metallic intermediate-temperature recuperative air heater but using oxygen enrichment of the combustion air.

The first base case power plant was to use a commercially available coal gasifier/cleanup system to separately fire the high temperature combustion air heaters. These heaters were to operate under conditions and in a temperature range that are within or only slightly beyond commercial experience. The second base case power plant was to use a gasifier/cleanup system that is either under development or requires a moderate extension of current technology to be implemented. The high temperature air heaters also were to require a moderate extension of current technology. The third base case plant uses a specified air separation plant of a type that has been used commercially.

This paper will briefly discuss the special features of each contractor's plants and summarize the performance and cost estimates for the plants. It will give the reasons behind the recommendation of a plant of the Case 3 type for first commercial use. It will compare the performance and cost estimates for one of each of the contractors' Case 3 plants. It will show that the primary reason for the performance difference between the two plants is a performance difference of the combustor/MHD generator combinations. It will show that the primary difference in the cost estimates of the two contractors lies in the estimated capital costs of the MHD topping cycle and in the estimated capital costs of the superconducting magnet subsystem in particular. It will investigate the reasons behind these performance and cost differences and show how performance considerations and cost estimates are related.

Base Cases and Variations

The specific characteristics of the three bases cases established by the two contractors and the range of parametric variations considered are summarized in Table 1. Both contractors used the commercially available low BTU (LBTU) Wellman-Galusha gasifier for Base Case 1 and all its parametric variations but adopted different approaches for sulfur removal. Avco used the Stretford process to remove the sulfur from about half the LBTU gas produced before combustion. The sulfur is removed from the remainder of the gas after combustion by the seed-sulfur reaction in the main MHD combustion gas stream where this portion of the combustion products is injected after leaving the high temperature air heater. GE relied on a spray-dryer flue gas desulfurization (FGD) process to remove the sulfur from the LBTU gas combustion products. All the plants in this study were designed to reduce potential SO_x emissions by 85 percent as required by the New Stationary Sources Performance Standards which had been proposed at the time of contract initiation. The final version of these standards[5] is somewhat different and would require only a 70 percent reduction in potential SO_x

TABLE 1

Base Cases

	Avco			GE		
	I	II	III	1	2	3
Plant Size, MWe	900 →	→	→	1200 →	→	→
Fuel Type/% Moisture as Fired	MR/5 →	→	→	MR/4.8 →	→	→
Combustor Type/% Ash Rejection	Single Stage/ 80 →	→	→	2 Stage/ 85	1 Stage/ 85	1 Stage/ 70
Oxidizer	Air	Air	34 mole % O_2	25.7 mole% O_2	Air	42 mole% O_2
Preheat Temp., F	2700	3000	1100	2700	3000	1300
Gasifier/Pressure	W-G/atmos	CE/atmos	-	W-G/atmos	2 Stage cyclone/press	-
Sulfur Cleanup	Stretford + Seed Reaction	Stretford	-	FGD	FGD	-
Generator Type	Diagonal →	→	→	Faraday →	→	→
Magnetic Field, T	6 (constant) →	→	→	6-5 →	→	→
Seed Concentration, %K	1 →	→	→	1	1	1.7
Other	Load = .8	Load = .8	Load = .79	Length = 25m →	→	→
Seed Regeneration	Formate →	→	→	None, FGD	Formate →	→
Bottom Cycle	Subcritical →	→	→	Supercritical →	→	→
Costed Parametric Variations Considered: Number/Type	9/Size, Coal, Preheat, Oxidizer, Generator Parameters	10/Coal, Preheat, Generator Parameters	6/Size, Coal, Oxidizer, Preheat	5/Combustor, Oxidizer, Generator Parameters	21/Size, Coal, Combustor, Gasifier, Generator Parameters	4/Coal, Combustor, Preheat, Generator Parameters

MR = Montana Rosebud Coal
W-G = Wellman-Galusha Gasifier
CE= Combustion Engineering Gasifier
FGD = Flue Gas Desulfurization (Spray Dryer)

TABLE 2

Summary of Results, Montana Coal, Max. Magnetic Field = 6T

	Avco			GE		
Base Case	I	II	III	1	2	3
Efficiency	42.1-43.2	44.3-45.0	42.9-44.8	41.4-41.8	42.3-44.3	42.6-42.9
Levelized COE (LEV=1.882)	43.99-46.30	43.33-45.40	40.38-41.61	55.08-56.25	51.54-57.85	52.73-52.98
Overnight Capital Cost $M mid 1978	679-708	708-756	593-609	1156-1202	967-1185	928-940
Overnight Capital Cost $/kW mid 1978	691-743	693-751	634-647	970-999	821-970	852-857
Constr. Period, Yrs	5.75	5.75	5.75	6.5	6.5	6.5
Power Output, MWe	916-1012	959-1038	919-961	1190-1203	1165-1282	1089-1099

emissions for the Montana coal used in the study and a 90 percent reduction for the Illinois coal.

For the second base case Avco used an atmospheric-pressure entrained-bed Combustion Engineering gasifier. This gasifier is in the development stage. A Stretford unit was used to remove sulfur from all the LBTU fuel gas produced. GE used a pressurized two-stage high slag rejection cyclone "gasifier" for its second base case plant and once again removed sulfur with a spray-dryer FGD unit. GE considered a number of gasifier parametric variations including a split-stream gasifier which also supplies fuel gas to the MHD combustor, a gasifier with in-bed desulfurization, and the regeneratively air-cooled coal combustor being developed as part of the closed-cycle MHD program.

For the third base case both contractors used an air separation plant specified by NASA. The characteristics of this plant were supplied by Lotepro Corp. under a contract to Gilbert Associates, Inc. The specified air separation plant produces a product containing 80 percent oxygen by volume with a power consumption of 203.5 kW-hr/ton of equivalent pure oxygen.

For the MHD combustor, Avco used a single-stage coal combustor with an assumed 80% ash rejection for all cases. GE used single-stage or two-stage cyclone combustors with an assumed 70% or 85% ash rejection for the majority of their cases. As mentioned above, for Base Case 2, GE also considered a split stream gasifier which supplies both the air heater and MHD combustors but found that this gasifier alone cannot supply fuel in the proper proportion for both uses. The MHD combustor must be supplemented with fuel gas from an additional gasifier or with a coal combustor. The first of these options gives a case with virtually complete ash rejection.

Plant Performance and Cost

Table 2 and Figure 1 summarize the performance and cost estimates made by each contractor. They compare both the results of the two contractors and the results for the different base cases for each individual contractor. So that the latter comparison can be made more meaningful, results for some of the parametric points have been omitted from the table and figure. Only a single plant size has been included for each contractor. Only cases using Montana coal have been included. Also, certain parametric cases which involved MHD generator parameter variations which led to high performance generators but which were considered only in one base case have been omitted.

The capital cost estimates given, both in dollars and in dollars per kilowatt of plant output, are "overnight" construction cost estimates and exclude interest and escalation during construction. The 30 year levelized cost of electricity (COE) is calculated in accordance with Reference 6. Table 3 lists the values of parameters used in calculating the COE. The contractors' COE estimates as presented in the final reports[1,2] have been recalculated where necessary to put them on the same basis.

Both contractors arrive at similar conclusions regarding the relative performance and cost of the three plant types considered. Table 2 and Figure 1 indicate and both contractors conclude that the Case 2 and Case 3 plants are comparable in both performance and cost and that the Case 1 plants are

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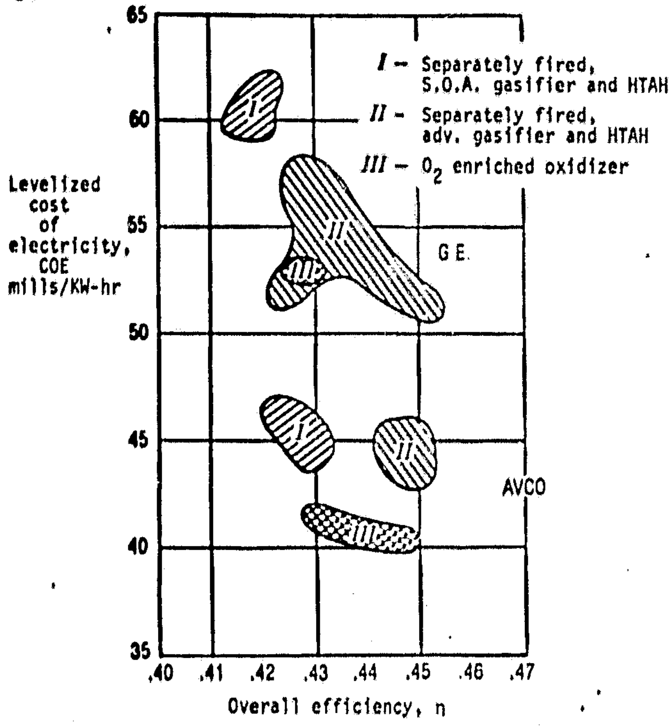

Figure 1. - Summary of PSPEC results

TABLE 3

Economic Parameters Used in Calculating Levelized Cost of Electricity

Capital Cost Portion including escalation and interest during construction

"Overnight" construction cost estimated by contractor

Construction period estimated by contractor

ECAS[3] cash flow curve during construction

6.5% annual escalation rate

10% annual interest rate

18% annual fixed charge rate

65% capacity factor

Fuel Cost Portion

$1.05 per million BTU mid-1978 fuel price

Operation and Maintenance (O&M) Cost Portion

Estimated by contractor

Fuel and O&M costs levelized with factor 1.882[6]

Escalation and interest as above

No real fuel price escalation

30 year plant life

Final levelized COE is in mid-1978 dollars

both lower in performance and higher in cost than the plants of the other two cases. Both contractors conclude that there is the potential for slightly better performance from the Case 2 plants than from the Case 3 plants. However, the COE for the Case 3 plants is either at or below the lowest COE for the Case 2 plants. There is, however, a difference in the level of the cost estimates between the contractors and the reasons behind this difference will be explored in the comparison of Base Case 3 plants below.

Comparison of Results for Oxygen Enriched Plants

One of each of the contractors' Base Case 3 oxygen enriched plants has been selected for making a comparison of the performance and cost estimates. The plants selected each have an oxidant preheat temperature of 1100F and are otherwise representative of each contractor's basic approach and assumptions as used throughout the study. Performance data for the two plants are given in Table 4. The difference in estimated performance between the two plants is relatively small. However, the much larger difference in estimated cost between the two contractors' plants is to some extent influenced by the design methods and choices that were made to achieve these similar efficiencies. For this reason, it is of particular interest to look at the performance of each plant in some detail.

Performance Comparison

The Avco plant has an overall efficiency of 43.4 percent compared with the GE plant's 42.6 percent. Table 5 lists some significant power ratios for each of the two plants. These ratios point to the sources of the efficiency difference between the two plants. The lower value for the ratio of power into the MHD generator to power into the MHD combustor for the GE plant is a reflection of the higher combustor heat loss used by GE. The GE generator has a lower enthalpy extraction than the Avco generator in spite of its greater length. The reasons behind this will be discussed below. The result is that a smaller part of the total plant output is produced by the topping cycle in the GE plant which tends to depress the overall efficiency. With one exception, the remaining power ratios are very similar for the two plants. The Avco plant includes a significantly higher estimate of the auxiliary power requirements which partially offsets the effects described above.

This comparison of power ratios shows that the higher performance of the Avco plant can be attributed to Avco's higher performance predictions for the combustor and generator. Because of their higher combustor heat loss assumption GE tended to use longer MHD generators, but their generator performance estimate was still lower than that of Avco. An important contributing factor to the difference in calculated generator performance is the difference in the performance calculation procedures themselves.

Table 6 summarizes the generator performance calculation approaches used and Table 7 summarizes the generator performance results. Each contractor sought to maximize the net topping cycle power (the MHD power generated less the power required to compress the oxidant) by the proper choice of combustor pressure and each contractor sought the level of oxygen enrichment which would give the best plant efficiency. They both used a quasi-one-dimensional (with boundary layer) design calculation but used different choices of independent and dependent variables along the length of the generator. Neither contractor's method as used provides for local control over electric "stresses" within the generator. Some of Avco's calculated electric stresses (Table 7) exceed what are generally held to be acceptable values. These stresses could be controlled by an appropriate tapering of the magnetic field at the cost of some increase in generator length but with no significant change in generated power.

In a previous paper[7], results are presented for a method of calculating MHD generator design performance in which the generator is operated in a manner such that both maximum net topping cycle power is achieved and such that the limiting value of one

TABLE 4

Comparison of GE Case 3.4 and Avco Case III-1

	GE 3.4	Avco III-1
Coal Input	2582 MW	2147 MW
Power Output	1100 MW	930 MW
DC Power-MHD	551 MW	523 MW
Shaft Power-Turbines	814 MW	636 MW
Power-Aux. & Losses	265 MW	229 MW
Overall Efficiency	42.55%	43.40%
O_2 Enrichment, vol %	42%	34%
Preheat Temp.	1100F	1100F
Steam Cycle	3500/1000/1000 (Supercritical)	2400/1000/1000 (Subcritical)
Levelized COE, mills/kW-hr	53.13	41.34
Plant Capital Cost, $/kW Plant Output	855	646

TABLE 5

Power Ratio Comparison

Power Ratio	Avco III-1	GE 3.4
MHD Generator Input / Combustor Input	.974	.932
MHD / MHD Generator Input (Enthalpy Extraction)	.225	.215
MHD / Power Plant	.538	.499
Bottom Cycle Output / Bottom Cycle Input	.434	.432
Oxygen Production / Coal Input	.029	.034
Auxiliary / Coal Input	.043	.029
Stack Loss / Coal Input	.090	.084
Other Losses / Coal Input	.022	.021
Coal to Seed Reprocessing / Coal Input	.011	.013
Overall Plant Efficiency	.434	.426

or more electrical stresses is attained at every point along the length of the generator. This method leads to channels with constant loading, a slightly tapered magnetic field and operation at the limiting value of the total electric field over most of the length of the generator. The particular independent variables and the values chosen for them by Avco result in generators that operate in a manner very similar to this. The choice of independent variables made by GE results in lower average electric fields and a lower average power density.

The possible improvement over the performance given by GE's basic method while still staying within electric stress limits is demonstrated by the alternative generator calculation used late in the study by GE itself for a few Base Case 2 points. In this method the transverse electric field is specified to be a constant value of 4kV/m for the entire length of the generator and the magnetic field becomes a dependent variable. The resulting generator is much closer to the Avco generators and the generators of Reference 8 in its operation. The alternative generator calculation gave a cycle performance improvement of one point over the basic calculation procedure in an otherwise similar GE Case 2 plant.

The conclusion to be drawn is that the performance difference between the Avco and GE plant could be narrowed if the generators were designed to operate in a similar manner. The GE generator could be shorter and achieve the same or a better enthalpy extraction while adhering to the same electric stress limits as before. Also one would expect a lower level of oxygen enrichment for a GE plant with the alternative generator. The Avco generator, as mentioned above, would increase somewhat in length if it adhered to the same electric stress limits as the GE generator.

Cost Comparison

Table 8 compares the estimated capital cost of the Avco and GE power plants. The capital cost is broken down into the major cost accounts specified to the

TABLE 6

Generator Design Calculation Comparison

Avco	GE
Specified at every axial location:	
Velocity (=constant) Magnetic Field (=constant=6T) Load Parameter (=constant)	Velocity Gradient (=constant) Magnetic Field (specified profile: 6T-5T taper with fringe field) Channel Area (cubic function of axial distance)
Other specified conditions:	
Inlet Stagnation Pressure and Temperature Inlet Mach Number Exit Pressure	Inlet Stagnation Pressure and Temperature Inlet Mach Number Exit Mach Number (=1) Exit Pressure Generator Length

TABLE 7

Generator Performance Comparison

	Avco III-1	GE 3.4
Mass Flow, kg/s	480	486
Inlet Stagnation Pressure, atm	8.3	9.3
Inlet Stagnation Temperature, F	4678	4805
Power Output, MW	523	551
Enthalpy Extraction, %	22.5	21.5
Length, m	19.7	25.0
Max. Transverse Current Density, A/cm^2	0.8	1.0
Max. Hall Field, kV/m	2.1	1.5
Max. Transverse Field, kV/m	4.0	4.1
Max. Hall Parameter	5.0	4.0
Average Power Density, MW/m^3	7.0	5.9

TABLE 8

Cost Comparison of GE Case 3,4 and Avco Case III-1

Cost Account	Equip. Cost $M		Total Cost $M		% of Total		$/KW Power Plant		$/KW MHD or Steam (As Approp.)		Total $/HRSR Duty ($/MW)	
	GE	AVCO	GE	AVCO	GE	AVCO	GE	AVCO	GE	AVCO	GE	AVCO
310 Land & Land Rights	-	.9	-	1.03	-	0.2	-	1.1				
311 Struct. & Improv.	34.8	23.0	98.8	49.5	10.5	8.2	89.8	53.3				
312 Boiler Plant	93.0	105.9	147.0	165.5	15.6	27.6	133.7	178.0	180.6	260.2	103.04	125.76
314 Turbogen. Units	58.6	31.9	94.0	47.0	10.C	7.8	85.6	50.5	115.5	73.9		
315 Access. Elec. Eqpt.	20.0	12.1	57.2	30.7	6.1	5.1	52.0	33.0				
316 Misc. P.P. Eqpt.	3.5	1.8	5.2	4.0	.6	0.7	4.8	4.3				
317 MHD Top. Cycle	257.1	133.1	389.3	187.0	41.4	31.1	354.3	201.1	706.5	357.6		
350 Transm. Plt.	6.5	3.7	7.4	5.0	.8	0.8	6.8	5.4				
Engin. Serv.			54.0	38.8	5.7	6.5	49.1	41.7				
Other Costs			-	10.0	-	1.7	-	10.7				
Oxygen Plt.			87.0	62.1	9.3	10.3	79.1	66.8				
TOTAL	782.7	312.4	939.9	600.5	100.0	100.0	855.4	645.8				

TABLE 9

MHD Topping Cycle Cost Comparison

Account		Costs in $/KW Power Plant Output: Equipment Cost AVCO	Equipment Cost GE	Total Cost AVCO	Total Cost GE+
317.1	Combustion Equipment	26.90*	28.21	44.26*	42.68
317.2	MHD Generator	5.69	21.11	7.13	31.92
317.3	Magnet Subsystem	47.31	97.20	57.72	147.46
317.4	Inversion Equipment	36.21	33.13	50.46	50.09
317.5	Oxidizer Preheat	12.64**	11.92	17.22**	18.03
317.6	Seed Subsystem	14.23	14.20	24.16	21.47
	Other (BOP)		28.21		42.67++
317	TOTAL	142.98	233.98	200.95	354.32

* Includes coal handling equipment (Avco Account 312.1) included by GE.
** Includes intermediate temperature air heater (Avco Account 312.42) included by GE.
+ Contingency cost has been distributed among subaccounts.
++ Breakdown into subaccounts not given by GE. Avco BOP is distributed among account.

contractors. Some modifications have been made in the cost breakdown given by the contractors so that a consistent comparison could be made. The equipment cost is the capital cost as delivered to site. The total cost includes direct and indirect site installation costs and a contingency allowance. The next two columns list the percentage of the total cost in each category and the total cost by category on a dollar per kilowatt of power plant output basis. The next column gives an amount in dollars per kilowatt of top or bottom cycle power for those accounts for which this is appropriate. In addition the boiler plant cost is given in dollars per unit of duty.

There are differences in many of the accounts. Among the accounts making up the larger shares of the total cost, the difference in Account 312 can be narrowed by accounting for the difference in relative duty of the Heat Recovery Seed Recovery System (Boiler Plant) within the two plants. The difference in Account 314 should be related to subcritical (Avco) vs supercritical (GE) turbines. The largest fraction of the power plant capital cost is in the MHD topping cycle and this makes the large difference in the contractors' estimates for this account the dominant factor in the difference in estimated capital costs.

Table 9 gives a breakdown of the MHD topping cycle account. The principal differences are in Subaccount 317.2, MHD Generator, and Subaccount 317.3, Magnet Subsystem. The magnet account is the largest subaccount under Account 317 and the 90 $/kW difference in the magnet accounts is the single largest difference in the cost estimates for Account 317. Table 10 gives a breakdown of equipment costs for magnets similar but not identical to the magnets in the plants being compared. Data of this kind for the specific plants under consideration was not available. Nearly the entire cost difference can be accounted for by the difference in the cost of the cold structure. There are large differences in both the total estimated weight and in the estimated cost per unit weight of the cold structure.

Several factors contribute to these differences:

1) The GE magnet is significantly larger than the Avco magnet. The GE magnet must accomodate a channel 5 meters longer than Avco's. Furthermore, GE assumed a significantly larger ratio of magnet warm bore exit area to channel gas flow exit area than did Avco. GE used a value of 3.0 for this ratio compared to the value of 1.8 used by Avco. Neither contractor selected his value on the basis of a detailed analysis. GE chose its value on the basis of the values used in past studies such as CDIF, ETF and ECAS. Avco's value is similar to that used in the BL6-1 design study[8]. PSPEC follow-on studies will address the question of the appropriate value of this ratio more closely and will choose a value on the basis of conceptual layouts for the generator and magnet.

2) There are basic design differences between the two magnets. The approach used by GE in PSPEC is a circular-saddle ring-girder design scaled from the BL6-1 magnet[8]. The approach used by Avco in PSPEC is a rectangular saddle design developed during the ETF study[9]. The latter design uses less material in the force containment structure by making more efficient use of it.

3) The large difference in the cold structure cost per unit weight can be attributed almost entirely to a difference in fabrication cost. The Avco ETF based design is claimed to require only the most simple machining and no welding[9], whereas the I-beam ring girders of the BL6-1 based design used by GE in PSPEC are more costly to fabricate[8].

Figure 2 summarizes the differences in the cost estimates for the two Case 3 plants being compared. The figure gives the sources of the difference in the levelized cost of electricity. The largest difference in the COE is attributable to the capital cost. The largest part of the capital cost difference is attributable to the cost of the MHD

TABLE 10

Magnet Equipment Cost as Delivered to Site*

AVCO I-1					GE 2.2				
	$	$/KW+	kgx10^6	$/kg		$	$/KW++	kgx10^6	$/kg
Structure	3,662,000	3.93	1.04	3.5	Cold Structure	60,800,000	55.33	6.08	10.0
Winding Assembly	24,109,240	25.90	2.20	11.0	Conductor	17,300,000	15.74	.86	20.0
Dewar	9,469,500	10.17	.76	12.5	Dewar	6,000,000	5.46	.38	16.0
Refrigeration System	2,943,570	3.16			Factory Labor	10,000,000	9.10		
Power, Controls	1,352,480	1.45			Site Labor (Assembly)+++	10,000,000	9.10		
					Miscellaneous	12,000,000	10.92		
TOTALS	41,536,790	44.61	4.0			116,100,000	105.66	7.32	

* Cost categories as used by contractors.
\+ $/KW power plant output for Case I-1.
++ $/KW power plant output for Case 2.2.
+++ Site assembly required to achieve same state as Avco magnet delivered to site.

topping cycle and the largest part of this difference is in turn attributable to the cost of the magnet subsystem. A small COE difference also results from a difference in construction period estimates. The remaining COE difference is largely a result of different operation and maintenance cost estimates. Neither contractor provided detail on these estimates. This portion of the COE will be reported more fully in the follow-on studies discussed below. The fuel cost portion of the COE is almost the same for each plant because of the similar overall plant efficiencies.

Conclusions

The results of the PSPEC study were among the factors involved in the recommendation adopted by the Department of Energy that the plants considered for first commercial use be of the intermediate temperature preheat type with oxygen enrichment of the combustion air as represented by Case 3. The oxygen enriched plant has an advantage over the separately-fired plant in simplicity as well as in the avoidance of a number of systems which require technological development. The oxygen enriched plant avoids the complexity of a gasifier system, gas clean-up system, and regenerative air heater system. Moreover, the advanced gasifier and regenerative heat exchanger systems of the Case 2 plants are either in the development stage or beyond the limits of operating experience. The oxygen enriched plant replaces the complex systems of the separately-fired plant with an air-separation plant that requires little or no technological development. On the other hand, a separately-fired system using "state-of-the-art" components in the air preheater system, Case 1, is clearly inferior in performance and cost to Case 3. The choice of a plant with oxygen enrichment for the first commercial plant allows a concentration of the development effort on the specifically MHD components of the plant which must operate properly for the implementation of any of the concepts considered in this study.

In accordance with the recommendation to develop the oxygen enriched plant, a second phase of the PSPEC contracts will study a plant of this type in more detail. Each contractor will conduct a study which will include a conceptual layout of plant components and which will allow a better estimate of performance and cost.

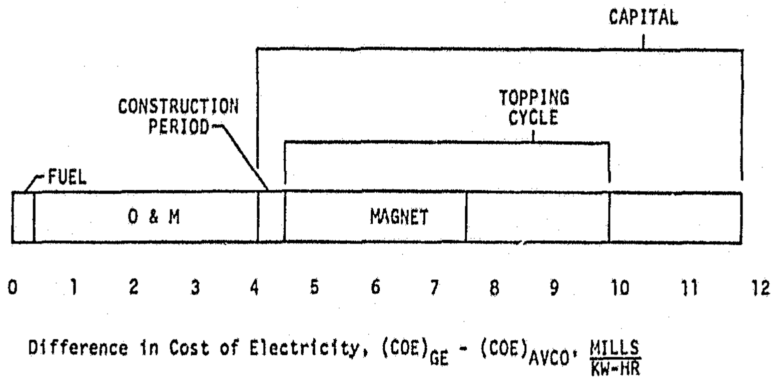

Figure 2. - Difference in Cost of Electricity between G.E. Case 3.4 and Avco Case III-1.

References

1. Parametric Study of Potential Early Commercial MHD Power Plants, Avco Everett Research Laboratory, Inc., DOE/NASA/0051-79/1, NASA CR 159633, December 1979.

2. Parametric Study of Potential Early Commercial MHD Power Plants, General Electric Company Space Sciences Laboratory, DOE/NASA/0052-79/1, NASA CR 159634, forthcoming.

3. Energy Conversion Alternatives Study (ECAS), General Electric Phase II Final Report, Volume II, Part 3, NASA CR 134949, December 1976.

4. Evaluation of Phase 2 Conceptual Designs and Implementation Assessment Resulting from the Energy Conversion Alternatives Study (ECAS), NASA TM X-73515, April 1977.

5. Federal Register, Part II, Environmental Protection Agency, New Stationary Sources Performance Standards; Electric Utility Steam Generating Units, June 11, 1979.

6. Comparative Study and Evaluation of Advanced Cycle Systems, Volume 2, Part 2, General Electric Company, EPRI AF-664, February 1978.

7. Pian, C.C.P., Staiger, P. J. and Seikel, G. R., MHD Performance Calculations with Oxygen Enrichment, DOE/NASA/2674-79/4, NASA TM 79240, June 1979.

8. Hatch, A.M., et al., Design of Superconducting Magnets for MHD Applications, Final Technical Report, Avco Everett Research Laboratory, USERDA FE-2285-7, June 1977.

9. Zar, J.L., Design and Cost for the Superconducting Magnet for the ETF MHD Generator, Final Report, AMP 582, Avco Everett Research Laboratory, April 1979.

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16. Abstract

The "Parametric Study of Potential Early Commercial MHD Power Plants" is described and the results of the study are summarized. Two parallel contracted studies were conducted. Each contractor investigated three base cases and parametric variations about these base cases. Each contractor concluded that two of the base cases (a plant using separate firing of an advanced high temperature regenerative air heater with fuel from an advanced coal gasifier and a plant using an intermediate temperature metallic recuperative heat exchanger to heat oxygen enriched combustion air) were comparable in both performance and cost of electricity. The contractors differed in the level of their cost estimates with the capital cost estimates for the MHD topping cycle and the magnet subsystem in particular accounting for a significant part of the difference. The impact of the study on the decision to pursue a course which leads to an oxygen enriched plant as the first commercial MHD plant is described.

17. Key Words (Suggested by Author(s)): Magnetohydrodynamics power generation; Oxygen enrichment; High temperature air preheat; Thermal efficiency; Plant capital costs; Cost of electricity

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